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INSTRUCTION BOOK

for

MODEL 350

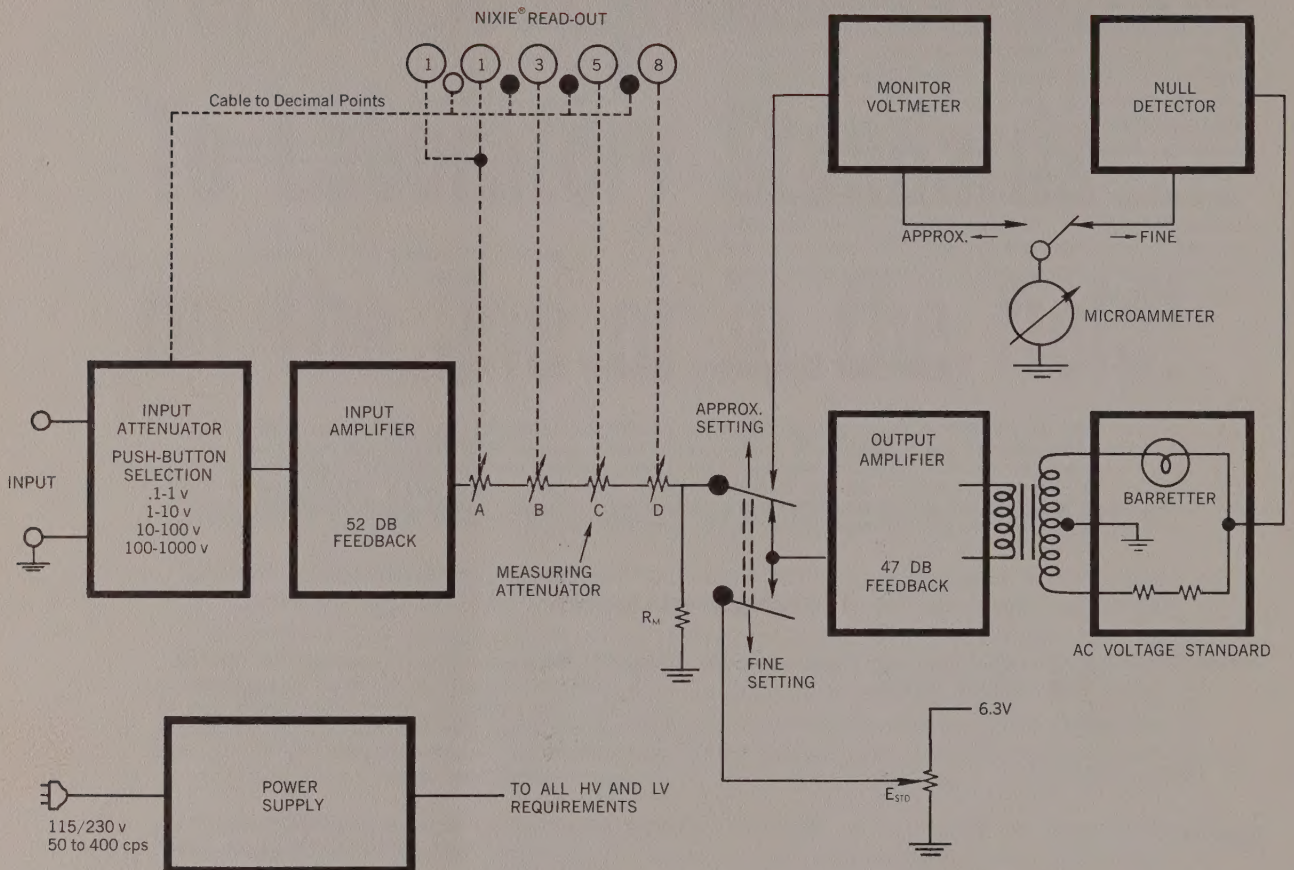
PRECISION RMS VOLTMETER

QC CAL CENT
PROCEDURES
GROUP COPY

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

BLOCK DIAGRAM OF MODEL 350



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BALLANTINE LABORATORIES INC.

Boonton, New Jersey

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JANUARY 1961

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BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

Printed in U.S.A.

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2. Check and adjustment of monitor voltmeter and null detector
3. Check and adjustment of measuring attenuator linearity
4. Check and adjustment of amplifiers and input attenuators, frequency response and accuracy
5. A 48 hours aging and crosscheck to assure instrument stability.

We will guarantee the performance to be within the original specification limits.

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(b) Package carefully, using plenty of cushioning

(c) Ship by air, railway express, or motor truck — **not** parcel post

Return shipment will normally be made within two weeks.

Ballantine Laboratories, Inc., 90 Fanny Road, Boonton, N. J.

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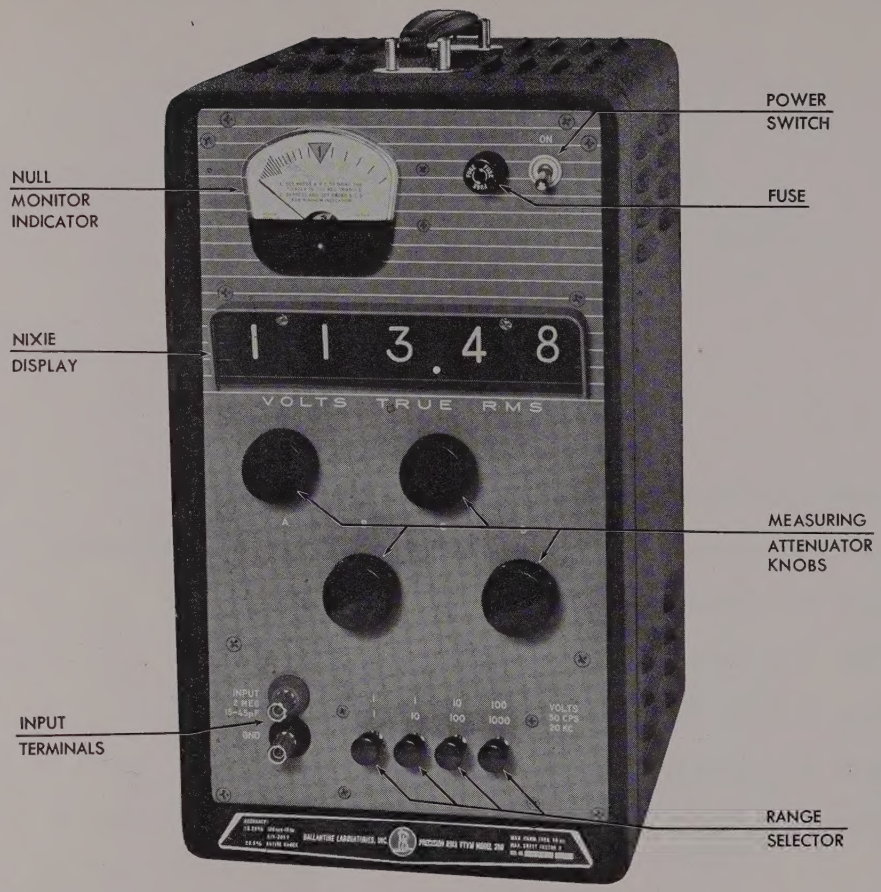


Figure 1A—Model 350 Precision RMS Voltmeter (Portable Model)

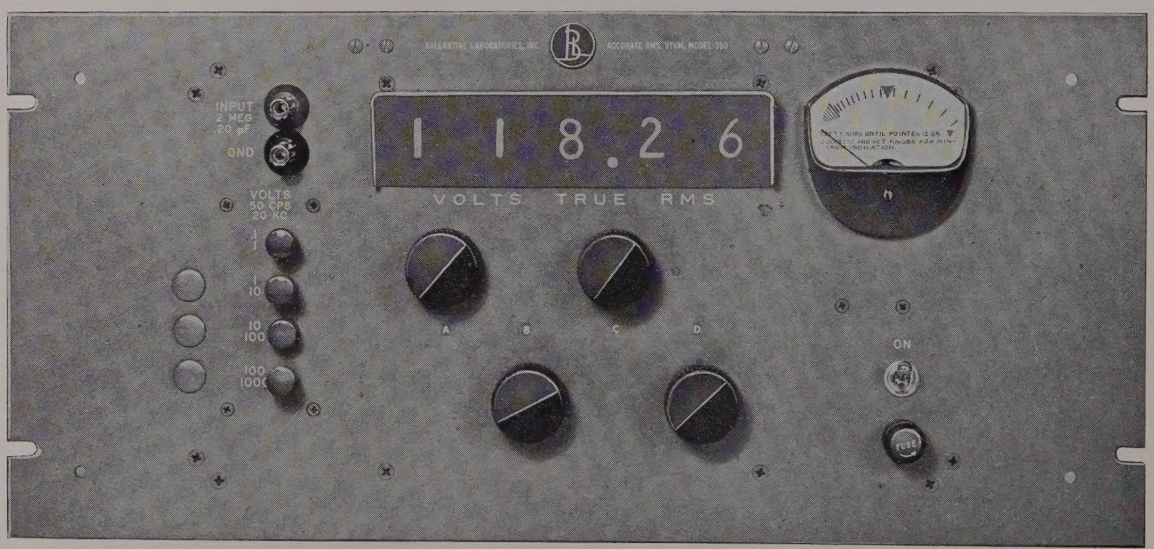


Figure 1B—Model 350 S/2 Precision RMS Voltmeter (19 inch Relay Rack Model)

1. GENERAL INFORMATION

1.1 Purpose and Use

The Ballantine Model 350 Precision RMS Voltmeter is a highly accurate instrument for true RMS voltage measurements. Utilizing a new principle, the instrument combines the accuracy of a laboratory standard with simplicity of operation, clarity of readout, ruggedness and long life. This combination makes standards laboratory accuracy available to the general laboratory or production line without requiring great care or special skill in handling and reading the instrument.

The Model 350 is a true rms-responding instrument for waveforms up to a crest factor of 2 (approximately 50% waveform distortion). For high accuracy measurements, the true rms response is extremely important because of the waveform error possible with average and peak responding instruments. For example, in the presence of 10% harmonics, the average or peak response will deviate 1% to 10% from the true rms response, depending on the type of response and the order and phase of the harmonics. For meaningful results with average or peak responding instruments, only very pure waveforms can be measured. This seriously limits the use of such instruments. The Model 350, however, accepts up to 50% harmonics, which makes the instrument usable and the results meaningful for most practical waveforms.

As compared to the normal laboratory standards of comparable accuracy (precision dynamometer, for example), the Model 350 is rugged and does not require the extreme care of a laboratory standard, such as very careful handling, levelling and tedious reading of the scales. It can be used in any laboratory, production line and even under field conditions. In common with well designed electronic equipment it will withstand moderate shock and wide environmental conditions.

The measuring procedure with the Model 350 is simple. Select the correct voltage range, set the knobs to bring the pointer of the indicator to mid-scale, and then depress and set the knobs for minimum indication. The unknown voltage can now be read easily, free of parallax error and with high precision from an inline NIXIE® four or five digit display. The procedure for setting of the knobs is very similar to the balancing of a common Wheatstone bridge. This does not require any special skill and is common knowledge to most laboratory and production line personnel. The precision of the Model 350 is approximately 5 to 10 times higher than the specified accuracy. This feature, in connection with the excellent stability of the voltmeter, makes the instrument usable beyond its accuracy limits for observation of small changes, comparison of two voltages, or for use as a precision transfer device.

The Model 350 is designed for reliable operation and long life. High grade, reliable components, such as RCA-Red instrument, 10,000 hour life tubes in amplifier circuits, special accurately matched, hermetically sealed resistors for measuring circuits, a voltage reference circuit with better than 0.01% stability per 1000 hour operation, and long-life silicon rectifiers in the hv power supply are used and ample negative feedback, with underrating of all components, applied to the amplifier circuits. Because of this, a total life in excess of 10,000 hours is expected from the instrument, with calibration stability of over 1000 operating hours.

1.2 Technical Characteristics

Voltage Range

0.1 V to 1199.9 V in four ranges:
0.1 V to 1.1999 V
1 V to 11.999 V
10 V to 119.99 V
100 V to 1199.9 V

Frequency Range

50 cps to 20 kc

Waveform

Sine or distorted waveform
Max crest factor 2
Max harmonic frequency 50 kc

Response

True RMS

Accuracy

Accuracy, 0.1 V to 300 V
±0.25%, 100 cps to 10 kc
±0.5%, 50 cps to 100 cps and 10 kc to 20 kc

For voltages above 300 V a correction must be applied as shown in Figure 2. The true rms voltage is always less than the indicated voltage by the amount shown on the graph.

Input Impedance

2 MΩ in parallel with
45 pF for 0.1 to 1 V range
20 pF for 1 to 10 V range
15 pF for 10 to 100V range
15 pF for 100 to 1000 V range

Equivalent Input Noise

Shorted input — below 100 μV
Open input — below 300 μV

Indication

Inline NIXIE® display with
Polaroid shield
4 digits from 1000 to 9999
5 digits from 9999 to 11999
Decimal point coupled
with the range selector

Warm Up Time

minimum warmup time 15 min.
less than 0.05% drift after 20 min.
less than 0.02% drift after 1 hour

Ambient Temperature Effect

less than ±0.005%/°C from 20°C

Line Voltage Range

105 V to 125 V
(210 V to 250 V)
50 cps to 400 cps

Effect of Line Voltage Change

Less than 1/10 of the specified accuracy

Power Consumption

60 W

Fuse

0.7 A (0.375A) slow blow

Tubes

3-5693	1 - OA2
2-5692	1 - OB2
1-12AX7	5 - NIXIE 6844-A or B-5031
1-12AY7	

Dimensions

Portable: 15"(H) x 8"(W) x 10"(D)
Rack: 8¾"(H) x 19"(W) x 9"(D)

Weight

19 lbs.

Shipping Weight

38 lbs.

2. OPERATION

2.1 Power Connection

The Voltmeter is supplied ready to operate at 105-125 V, 50 cps-400 cps, or 210-250 V, 50 cps-400 cps power line, as indicated on the decal mounted adjacent to the power cord.

2.1.1 Line voltage conversion from 115 to 230 V operation or vice versa is possible. Detailed instructions are given on the schematic diagram at the end of the instruction book.

2.2 Starting Procedure

Insert the three prong plug into the proper ac power outlet. Use conversion unit when two prong outlets are available. Move the power switch to ON position. The NIXIE tubes should light up. The instrument is ready to use after a short warmup period.

2.2.1 Warmup period

A minimum 15 minute warmup period should be allowed during which the normal operating temperature of the crystal oven, which houses the AC Voltage Standard, will be established. During this period the voltmeter sensitivity may change up to a few percent. After the 20 minute warmup, the instrument is stabilized so that further drifts will be below 0.05%; after one hour operation, the instrument is completely stabilized.

When the instrument has not been in use for many months and has been stored in high humidity, several hours of warmup are recommended before making measurements to maximum accuracy.

Permit air to circulate freely around the voltmeter to avoid excessive temperature rise of the instrument.

2.3 Function of Controls

Range Selector:	Selects Voltage Range
0.1-1 depressed:	Voltage range 0.1-1.1999 V
1-10 depressed:	Voltage range 1-11.999 V
10 -100 depressed:	Voltage range 10-119.99 V
100-1000 depressed:	Voltage range 100-1199.9 V
Knobs ABCD:	Control of measuring attenuator. To be set to the unknown value of input voltage.
Knobs ABC Released:	For approximate setting until the indicator points to the middle of the red triangle at midscale.
Knobs BCD Depressed:	For accurate setting until the indicator shows a minimum at extreme left side of the meter scale.
NIXIE display:	Display of the unknown voltage after correct setting of the knobs.
Power Switch ON:	Turns the instrument on
OFF:	Turns the instrument off

2.4 Voltage Measurement

2.4.1 If the magnitude of the voltage is known, the proper voltage range should be selected by depressing the range selector button of the range which includes the unknown voltage.

2.4.2 If the magnitude of the voltage is not known, proceed as follows:

SET	TO
Range Selector	100 V-1000 V
Knob A	Completely counter-clockwise (First lighted digit 1)
Knob B	Second digit 0
Knob CD	Any setting

Connect the unknown voltage to the input binding posts. Depress the range selector buttons from higher

to lower range until the indicator indicates on or to the right of the red triangle. The unknown voltage is in the highest range which gives this indication.

2.4.3 For approximate setting of the knobs ABC, starting with knob A, turn the knobs without depressing until the indicator points to the middle of the red triangle.

Turn the knobs clockwise when the pointer is to the right of the triangle, counterclockwise when it is to the left of the triangle.

When the pointer is on the middle of the triangle, the knob setting is a few percent lower than the correct setting so that, for final setting, the knobs always have to be turned clockwise.

2.4.4 For final and accurate setting, depress and turn knobs BCD until the indicator shows a minimum deflection as far left from the center triangle as possible. Start with knob B and turn the knobs clockwise as long as the indication decreases. When the minimum is passed and the indication starts to increase, turn the knob one step back and repeat the procedure with the next knob.

When turning the knob, note the setting of the NIXIE display. Every time the digit 9 is passed, when turning the knobs clockwise (increasing numbers), the higher digit should be advanced by one step, or decreased by one step when 0 is passed by counterclockwise turning (decreasing numbers).

Check the correctness of the minimum by changing the last digit approximately $\pm 0.1\%$. The indication should clearly increase due to the change of setting in either direction.

2.4.5 The magnitude of the indicated minimum may be different at different frequencies and may vary between different instruments. From 100 cps to 10 kc the minimum is normally in the arrowhead. At 50 cps and 20 kc it may be above the arrowhead. For correct measurement, the magnitude of the minimum is not important.

2.4.6 A time delay of a few seconds is built into the knob switch. This allows movement of the hand from one knob to the other without changing the operating mode of the voltmeter. After the release of all knobs, the instrument automatically switches into the approximate setting mode.

2.5 The precision or repeatability of the measurement depends on the frequency and waveform of the measured voltage. If one half of a division is considered as a smallest observable indication, the following precision figures are typical:

FREQUENCY	PRECISION
50 cps	0.06%
100 cps	0.03%
1 kc	0.02%
10 kc	0.03%
20 kc	0.04%

The precision may vary slightly between voltmeters.

2.6 Measurements with higher precision, approximately half of the quoted figures, is possible when a different technique to set the minimum is used:

2.6.1 Set the minimum in the regular manner as described under 2.4.4.

2.6.2 To check the correctness of this setting, change the setting of knob C or D clockwise and counterclockwise by approximately 0.1% of the indication. The change in both directions should be an equal number of steps (digits). Observe the change in the null indicator. If the original setting was correct, the increase of indication in both directions will be the same. If that is not the case, the original setting should be corrected until the turning of the knobs in either direction by equal steps produces the same deviation from minimum setting.

Using this method, the precision of the measurement exceeds greatly the guaranteed accuracy. However, such measurements may be useful when very small changes of a voltage have to be observed or two voltages compared to high precision.

2.7 The dc component of the input signal is not measured. The maximum allowable dc component is 600 V. In case the dc component exceeds 600 V an external blocking capacitor with proper dc rating and with a minimum value of 0.1 μF may be used.

2.8 Maximum safe input signal depends on the setting of the range selector:

RANGE	MAX. INPUT
0.1 V-1 V range	50 V
1 V-10 V range	500 V
10 V-100 V range	1200 V
100 V-1000 V range	1200 V

The instrument will not be damaged if the overload is in the limits specified above, because the amplifiers will withstand the overload and the AC Voltage Standard is normally out of the circuit.

When the knobs B, C or D are depressed, the AC Voltage Standard is in the circuit and receives an overload when higher than normal voltage is applied to the input. By the design of the amplifiers, the overload is limited to the degree which is not damaging when applied over short periods of time. When a severe overload is applied over several hours, accelerated aging of AC Voltage Standard may take place and the instrument sensitivity may change.

To avoid this situation **the knobs BCD should never be clamped in the depressed position.**

2.9 Measuring voltage above 300 V will cause the input attenuator resistors to warm up and change the attenuation ratio. This warmup will require a few minutes during which the readings may drift slightly. In order to bring the measurements into ±0.5% limits a correction should be applied to the measured value. The amount of the correction is shown on the graph below, which should be applied to the value measured after the drift has occurred.

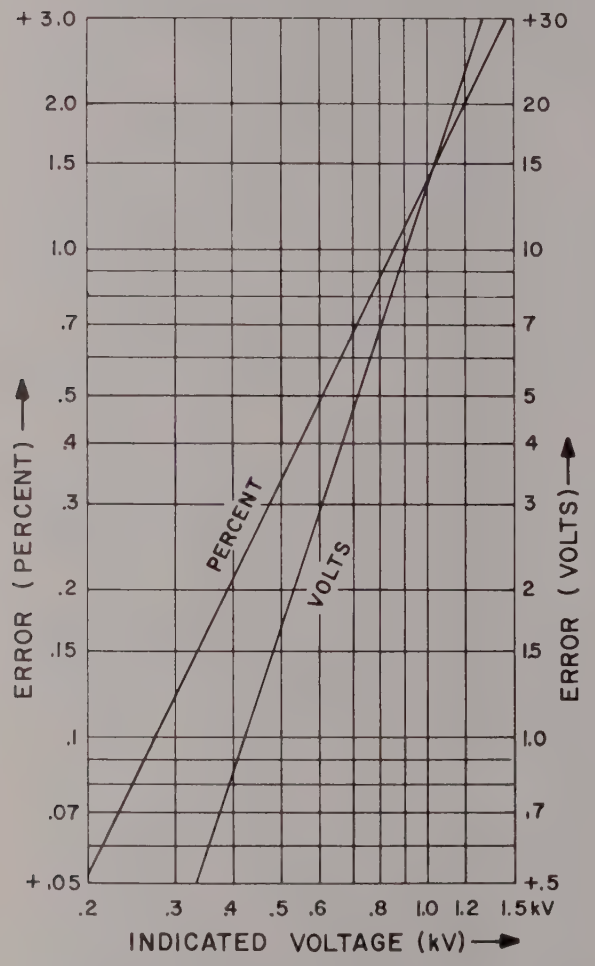


Figure 2 — Measuring Error Above 200 V

Example: After a few minutes waiting, a voltage 807.5 V is measured. From the graph above this reading is in error by +0.9% or +7.3 V. The correct voltage is:

$$807.5\text{-}7.3 = 800.2 \text{ V}$$

or using percent correction:

$$807.5\ (1\text{-}0.009) = 800.2 \text{ V}$$

2.10 When measuring distorted waveforms two limitations should be considered:

2.10.1 The maximum crest factor (ratio of peak to rms value) should not exceed 2.

2.10.2 The highest harmonics should not extend beyond 50 kc.

In these limits the basic instrument accuracy is within guaranteed specifications.

If the limitation is exceeded, the instrument may not give the proper rms response because the amplifiers may be overloaded or higher harmonics cut off. How much this condition affects the true rms response depends on the waveform. A universal formula to correct the response error cannot be given. The error for a specific waveform and voltmeter could be determined by a comparison with an accurate true rms responding device, such as an NBS Transfer Standard voltmeter. In general, this correction will hold to all voltage ranges if the crest factor does not exceed 3 and the maximum harmonic frequency 100 kc.

2.11 When measuring sources which have a connection to the power line, the connection of the third prong of the power line to the chassis and input ground terminal should be considered. In case the low terminal of the source has any potential against the ground, a ground current will flow through the chassis which may disturb the measurement or cause short circuits in extreme cases. This condition of measurement should be avoided.

Both power prongs of the line cord are insulated from the chassis by the insulation of power transformer, which may be several hundreds of megohms in parallel with a few hundred picofarads.

2.12 The Model 350 can be used to set the output voltage of a source to any value within the voltage range of the voltmeter. For that purpose, the dials of the Model 350 are set to the desired value. The source is connected to the voltmeter and the output of the source changed until the indicator indicates on the red triangle. Now the knob B, C or D is depressed and the output from the source changed until a sharp minimum on the voltmeter indicator is observed.

2.13 Possible Error Sources

To utilize the Model 350 to its best accuracy, certain precautions common to accurate measurements should be taken. The most common error sources are the effect of the ground currents, possible high frequency or 60 cps stray field pickup in measuring leads, and the loading effect of the input impedance. The nature of these errors is described in the paper, "Errors and Techniques in High Frequency Voltage Calibration" by Wallace F. White and Dr. Endel Uiga, a copy of which may be obtained from Ballantine Laboratories upon request.

3. CIRCUIT DESCRIPTION

3.1 Principle of Measurement

The Model 350 utilizes a new method for ac voltage measurement. A similar idea for dc voltage measurement is used in the Type K potentiometer.

The principle of measurement is shown on the following diagram:

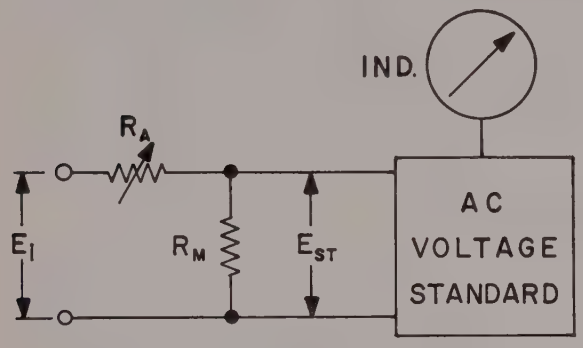


Figure 3 — The Principle of Measurement

The basic elements of the circuit are an accurate AC Voltage Standard and a precision resistive attenuator, consisting of a measuring resistor R_M and an adjustable attenuator resistor R_A.

The AC Voltage Standard is a device which indicates when a known constant voltage E_{ST} appears across its input. The indication of this condition is a very sharp decline of the output which can be observed with a sensitive but inaccurate indicator. When care is taken that the output from AC Voltage Standard is at minimum, a constant known voltage appears at the input of the standard and it can be considered in principle very similar to a dc standard cell.

To utilize the AC Voltage Standard for voltage measurement over a wide voltage range, it is combined with a calibrated variable voltage divider R_A and R_M. The attenuation in this divider is set so that for any input voltage E_i the standard voltage E_{ST} appears at the input of the voltage standard, which is indicated by the sharp minimum on the indicator. Under these conditions, the attenuator setting or value of R_M must be:

$$\frac{R_M}{R_A + R_M} = \frac{E_{ST}}{E_i} \qquad \text{or}$$

$$E_i = E_{ST} \cdot \frac{R_A + R_M}{R_M} = E_{ST} \left\{ \frac{R_A}{R_M} + 1 \right\}$$

Because R_M and E_{ST} have a known and constant value, the unknown input voltage can be obtained from the setting of the attenuator resistor R_A. In fact, when the attenuator resistor is calibrated in terms of the measuring resistor R_M and a digit 1 is added to the R_A setting, the scale for R_A can be calibrated directly in terms of the input voltage. The whole measurement problem is reduced to the setting of R_A until the output from the AC Voltage Standard indicates a minimum.

Example: Assume $E_{ST} = 1.000$ V

R_A = 4 decade resistance box. 10 kΩ, 1 kΩ, 100 Ω and 10 Ω per decade.

$R_M = 10$ kΩ.

A voltage measurement is made and an R_A setting of 64,350 Ω is required for minimum output from the AC voltage standard. From formula

$$E_i = E_{ST} \cdot \left\{ \frac{R_A}{R_M} + 1 \right\} = 7.435 \text{ volt.}$$

It can be seen that when the dial 10 kΩ decade is advanced by one step the unknown voltage can be read directly from the setting of R_A.

3.2 The AC Voltage Standard

The accuracy and stability of the measurement depends directly on the quality of the AC Voltage Standard. Its principle of operation is explained by the following drawings:

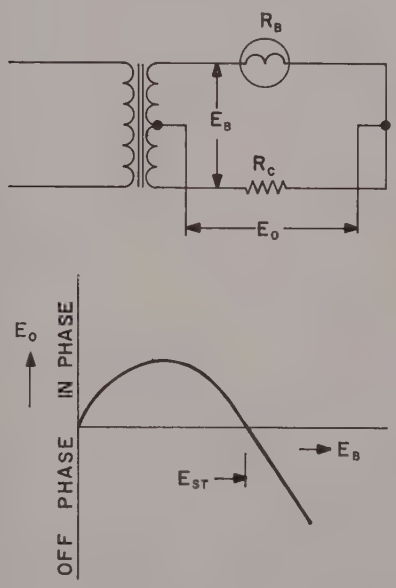


Figure 4 — AC Voltage Standard

The AC Voltage Standard is a bridge circuit in which two arms are formed by a center tapped transformer. A constant resistor R_C and a barretter R_B form the other two arms of the bridge. The input voltage E_B is fed to the bridge over the transformer. The output is taken from the center tap of

the transformer and the junction of R_B and R_C. The resistor R_C is chosen so that its value is higher than the resistance of the barretter at the normal temperatures. Therefore, the bridge is initially unbalanced and an output E_O is observed when voltage E_B is applied to the bridge. However when the bridge voltage is increased, the current through the barretter will increase, the filament will heat up and its resistance will increase. At some input voltage, the bridge will be balanced and no output from the bridge can be measured. With further increases of bridge voltage, the bridge is off balance again and its output will increase with increasing bridge voltage.

By the proper design, the bridge can be made a very precise and accurate voltage standard which balances at exactly the same input voltage E_{ST} over a wide frequency range.

3.4 Input Attenuator consists of four separate compensated decade attenuators with attenuation ratios 1 ÷ 1, 1 ÷ 10, 1 ÷ 100 and 1÷ 1000. This extends the basic voltage range 0.1 - 1 V up to 1000 V. Attenuator settings are coupled to the decimal point of the read-out.

3.5 Input Amplifier is a stable, 3 stage (Tubes V1, V2) feedback amplifier, which amplifies the 0.1 V input level to the approximate 0.5 V standard level required by the AC Voltage Standard. The amplifier is stabilized by 52 db of negative feedback, which also provides means to adjust the gain to allow for variations in voltage standards input level and to adjust the sensitivity of the instrument.

3.6 Measuring Attenuator is a four dial decade resistor box with the decade values 10 x 10 kΩ, 9 x 1 kΩ, 9 x

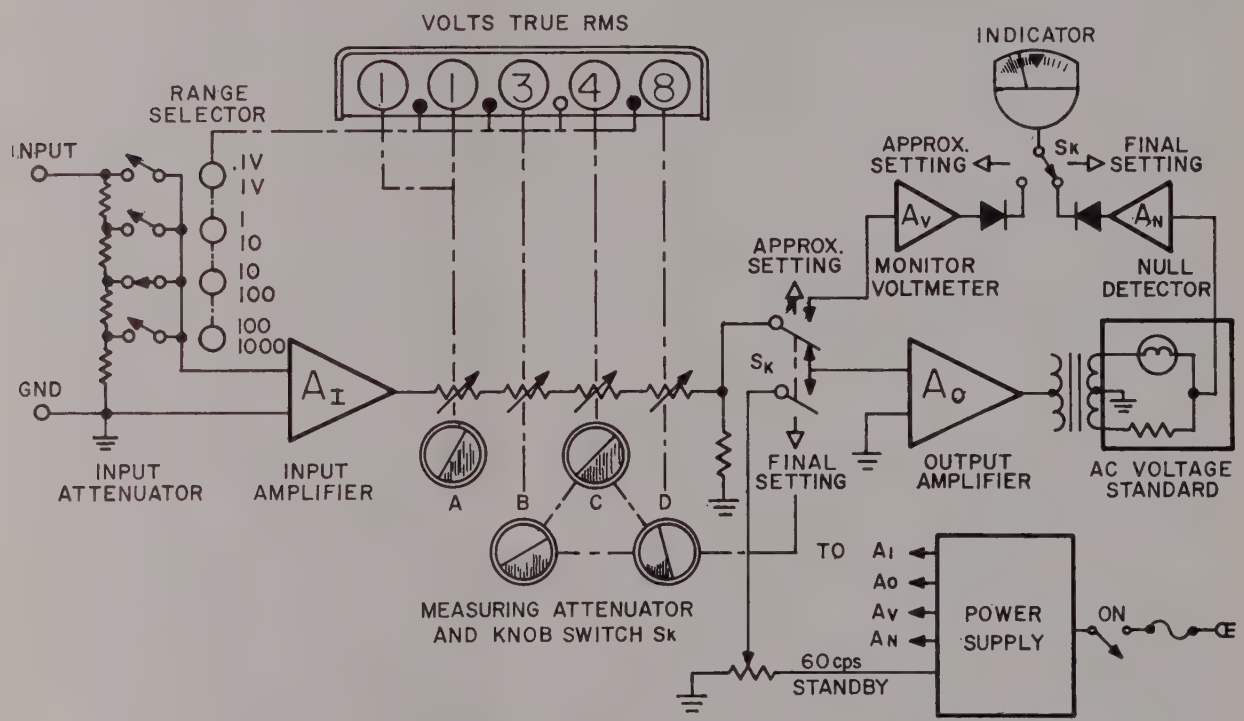


Figure 5 — Block Diagram of Model 350

Extreme care is taken with the design of the bridge. By selecting the proper components and keeping the sensitive elements in a temperature-controlled oven, a voltage stability of a few hundredths of 1%, with a resolution up to 0.01%, can be achieved over the instrument's frequency and operating temperature range. By proper design of the barretter, its life is extended almost indefinitely and aging effects are reduced to less than 0.01% per 1000 hours of operation.

3.3 Block Diagram of the Voltmeter

For safe and easy operation of the voltmeter, several auxiliary circuits have to be added to the basic measuring circuit. Those are explained in the block diagram of the whole voltmeter.

0.1 kΩ and 9 x 0.01 kΩ. Four accurate resistors with values 5, 2, 2, and 1 are used in every decade. With proper switching these will give all decade values.

With a 10 kΩ measuring resistor, R42, attenuation from 1 to 11.999 is achieved. The setting of the attenuator is coupled to the NIXIE tube read-out. A digit 1 is added to the first decade so that the input voltage can be read directly from the setting.

3.7 Knob Switch Sk is a relay switch which is activated by depressing the attenuator knobs B, C or D. When depressed, the unknown voltage is fed to the AC Voltage Standard for accurate measurement. When released, the unknown voltage is fed to a monitor voltmeter for approximate indication of the voltage. This provides a quick means for the coarse set-

ting of the knobs. During this procedure, the unknown voltage is disconnected from the AC Voltage Standard and a 60 cps voltage of approximately E_{ST} value is fed to the AC Voltage Standard. This prevents the overloading of the voltage standard when excessively high voltage is applied to the voltmeter. It also keeps the filament of the barretter at the correct temperature and so reduces the warm-up time.

3.8 Output Amplifier is a stable, 3 stage (Tubes V8, V9, V10) feedback amplifier which provides the necessary power to feed the AC Voltage Standard. The gain of the amplifier is 1 and it is stabilized by 47 db feedback.

3.9 AC Voltage Standard is a nonlinear bridge, as described under 3.2. It is temperature and frequency compensated and is mounted in a crystal oven for greater stability against ambient temperature variations.

3.10 Null Detector is a high gain 3 stage amplifier (tubes V12, V11) and rectifier circuit to amplify and indicate the unbalance of the AC Voltage Standard.

3.11 Monitor Voltmeter is a one stage (½ tube V11) amplifier-rectifier circuit to indicate the approximate level of the signal after the measuring attenuator. It is adjusted so that, for correct level, the indication is on the red triangle at mid-scale.

3.12 Indicator is a 100 μA, sensitive, moving coil instrument which, by means of the knob switch relay, can be connected to the monitor voltmeter or to the null detector output.

3.13 The Power Supply consists of a voltage doubler silicon rectifier B+ supply with gas tube regulation and two filament supplies.

4. MAINTENANCE

4.1 General

The Model 350 voltmeter is designed for extended trouble-free life by using long-life, instrument-type tubes in critical circuits and by underrating the components. Operation of 4000 hours is expected without the need for a component or tube change.

The purpose of the maintenance procedure is to check the condition of the instrument and detect or correct the deteriorated components before they have an appreciable effect on instrument preformance.

When a tube has to be changed, only the sensitivity of the instrument may need readjustment. There is no need for extensive recalibration.

4.2 Recommended Maintenance Procedure consists of two types of periodic checks:

4.2.1 A 1000 hour check for every 1000 hours of operation.

4.2.2 A 2000 hour check for every 2000 hours of use.

4.3 Necessary Maintenance Equipment

4.3.1 A stable ac voltage source, 0.4 to 2 kc, 0.1 V to 100 V output (10 V is sufficient for most of the tests), and 0.01% short time stability. Ballantine Model 420 is recommended.

4.3.2 A variable frequency oscillator, 50 cps to 20 kc, 0.1 to 10 V output.

4.3.3 An accurate 0.05% or better true rms-responding standard voltmeter, voltage range 0.5 V to 100 V, such as NBS Transfer Standard Voltmeter.

4.3.4 Ratio Transformer $\pm$0.01% or better ratio accuracy over 10 to 1 range.

4.3.5 Variable, metered ac power supply 70 W.

4.4 Removal of the case is required for several of the tests. For the removal:

4.4.1 Place the instrument on a bench with front panel down.

4.4.2 Remove the power cord and unscrew, from the back, three #10 binder head screws.

4.4.3 Lift up the case.
To put the instrument back in the case proceed in reverse order.

WARNING . . . When instrument is operated without the case, the danger of electric shock exists. The highest voltage on one chassis is approximately 450 V dc. CARE SHOULD BE TAKEN NOT TO COME IN CONTACT WITH HIGH VOLTAGE POINTS.

4.5 1000 Hour Check

The purpose of the 1000 hour check is to check the performance of the instrument as a whole to detect unexpected failure of any tube or component.

4.5.1 The check consists of the following tests:

4.5.1.1 Test of the operation of the knob switch and NIXIE display.

4.5.1.2 Test of the accuracy of monitor voltmeter.

4.5.1.3 Test of the sensitivity of null indicator.

4.5.1.4 Test of the accuracy of the voltmeter.

4.5.2 Test of the NIXIE display and knob switch
4.5.2.1 To test the operation of the NIXIE display, turn all four measuring knobs through all positions. In every position the proper NIXIE number should light up. Dark parts on some of the numbers will indicate the deterioration of the tube. It should be replaced according to 5.3.4.

4.5.2.2 To test the knob switch connect a voltage of 0.4 to 2 kc to the voltmeter and set the knobs for minimum deflection on indicator. Release the knobs BCD. After 1-2 seconds the volt-

meter should change to the approximate measuring mode, which is indicated by change of the minimum deflection to the mid-scale. The change of the mode should occur by depressing any of the knobs BC or D. If the operating mode of the voltmeter does not change, see 5.3.7 for servicing.

4.5.3 Test of the accuracy of the monitor voltmeter Connect 0.4 to 2 kc signal source (4.3.1) to the voltmeter, set knobs for minimum deflection. Release the knobs. The indication on the indicator should be approximately 1/32" to 1/16" to the left of the center of the red triangle.

If the indication deviates from the limits see 5.6 for servicing.

4.5.4 Test of the sensitivity of the null detector

4.5.4.1 Connect a signal 0.5 to 0.6 V (or 5V to 6 V) 0.4 kc to 2 kc, to the voltmeter. Set the knobs for minimum indication. Observe the indication.

4.5.4.2 Set the last knob 2 digits higher or lower. Observe the increase on null indicator deflection. It should be approximately 1 scale division or more (1/16" approx.).

If the change of the indication is less than 1 division, the null detector sensitivity it not adequate and the circuit should be checked according to 5.5.2.

4.5.5 The test of the accuracy of the voltmeter should be performed at least on the 0.1 to 1 V range, and on any other range which is important to the user. For the test:

4.5.5.1 Connect the standard voltmeter (4.3.3) and the stable source of 0.4 kc to 2 kc to the input of the Model 350. Set the source voltage between 0.4 and 0.7 V. Measure the voltage with the standard voltmeter and with the Model 350. Calculate the percentage difference between the two results.

4.5.5.2 The difference (error of Model 350) should not exceed 0.15%. If the Model 350 is in error more than 0.15% but less than 0.3%, set the sensitivity of the Model 350 by adjusting R13. If the error exceeds 0.3% follow tests 5.8.

4.5.5.3 Repeat the test on other voltage ranges.

4.6 2000 Hour Check

The purpose of the 2000 hour check is, in addition to the performance check, to check the condition of the tubes and subassemblies. This is done by checking the performance of the assemblies under reduced line voltage. This condition will exaggerate the weakness of any deteriorated tube or component.

4.6.1 The 2000 hour check consists of

4.6.1.1 Test of the change of voltmeter sensitivity with reduced line voltage.

4.6.1.2 Test of the change of null detector sensitivity with reduced line voltage.

4.6.1.3 Test of the change of monitor voltmeter sensitivity with reduced line voltage.

4.6.1.4 Test of the linearity of the measuring attenuator.

4.6.1.5 The tests 4.5.2 and 4.5.3 as specified for 1000 hour check.

4.6.1.6 Test of the frequency response and error of every voltage range.

4.6.2 The test of the line voltage effect on voltmeter sensitivity will detect any deteriorated tube in the amplifier circuit. For the test:

4.6.2.1 Connect the Model 350 to variable power supply (4.3.6), set the line voltage to 115 V $\pm$1%.

4.6.2.2 After complete warmup (1 hour) feed a 0.4 kc to 2 kc stable signal of any amplitude to the Model 350. Measure the signal accurately, note the result.

4.6.2.3 Lower the line voltage to 100V $\pm$1%, wait 2 minutes, measure the same signal again, note the result.

4.6.2.4 Calculate the percentage difference between two measurements. It should be less than 0.1%.

If the measurements differ more than 0.1%, check the amplifier tubes V1, V2, V8, V9 and V10 for transconductance. Replace the tubes if the transconductance is below manufacturer's limits.

4.6.3 The test of the line voltage effect on the null detector circuit will detect any deteriorated tubes in this circuit. For the test:

4.6.3.1 Connect the Model 350 to the power line of 100 V $\pm$1% voltage.

4.6.3.2 Feed any stable 0.4 kc to 2 kc signal to the voltmeter, measure the signal, and note the minimum on the null indicator.

4.6.3.3 Reset the knobs C or D to lower and higher values until the null indicator pointer moves up 2 divisions (approx. 3/32") on the arrowhead part of the scale. Note the higher and lower setting of the knobs.

4.6.3.4 Calculate the percentage difference between the two settings. It should be 0.4% or less. If the difference is more than 0.4%, the tubes V11 and V12 should be checked for transconductance and changed if low.

4.6.4 The test of the line voltage effect on monitor voltmeter sensitivity will detect any deterioration of

any tubes and components in the monitor voltmeter circuit. For the test:

4.6.4.1 Connect Model 350 to variable power supply, set the line voltage to 115 V ±1%.

4.6.4.2 Feed a stable 0.4 kc to 2 kc signal to Model 350, set the released knobs so that the monitor voltmeter indicates exactly in the middle of the red triangle. Note the voltmeter setting.

4.6.4.3 Lower the line voltage to 100 V ±1%, wait 2 minutes, and reset the knobs to produce the same midscale indication. Note the setting of the voltmeter.

4.6.4.4 Calculate the percentage difference between the two settings. It should be less than 2%. If the difference exceeds 2% check Tube V11 for transconductance and replace if necessary. When a tube is replaced readjust monitor voltmeter sensitivity according to 5.6.

4.6.5 The test of the linearity of the measuring attenuator will check the condition and adjustment of the measuring attenuator. For the test:

4.6.5.1 Connect a stable 0.4 kc to 2 kc 10 Volt source to the Model 350 through an accurate Ratio Transformer (4.3.4).

4.6.5.2 Set voltmeter to 1 to 10 V range, knob setting 1.000. Set ratio transformer ratio to 0.1000. Adjust the output of the voltage source to give minimum indication on null indicator (knobs depressed).

4.6.5.3 Keep the source voltage constant, and set ratio transformer ratio to 1.0000. Measure the output from the transformer with the Model 350. The measured value should be from 9.995 to 10.005.

4.6.5.4 Repeat step 4.6.5.2 to make sure that the source voltage has not changed during the measurement.

4.6.5.5 If the measurement 4.6.5.3 is outside of 9.995-1.0005 limits adjust R46 according to 5.11 to bring the decading of the attenuator to the limits.

4.6.5.6 From setting 1.0000, step down to the setting 0.1000 in 0.1 steps (0.9000, 0.8000, 0.7000 etc.) and measure the voltage at every setting of the ratio transformer. It should be 10.000, 9.000, 8.000, . . . 1.0000 accordingly. The deviation from those values should not exceed ±0.05%. If the limits are exceeded follow 5.11 for corrections.

4.6.6 Make test 4.5.2 and 4.5.3 as described under 1000 hour tests.

4.6.7 Test of the frequency response and accuracy is done on every voltage range at the lower end of the range:

0.1 to 1 V range	test with 0.1 to .15 V
1 to 10 V range	test with 1.0 to 1.5 V
10 to 100 V range	test with 10 to 15 V
100 to 1000 V range	test with 100 to 150 V

4.6.7.1 For the test, connect a voltage source of 1 kc to 10 kc, 1 V to 100 V output, and a standard voltmeter to the input of the Model 350. Using the voltage listed above, feed a 1 kc and 10 kc signal to the Model 350. Measure the signals with the Model 350 and standard voltmeter. Calculate the percentage difference (error of Model 350).

4.6.7.2 The error limits are

1kc measurements ±0.15%

10 kc measurements ±0.2%

If the error exceeds the limits the voltmeter should be readjusted according to 5.9 and 5.10.

5. SERVICE AND TROUBLE SHOOTING

5.1 General

In case of voltmeter malfunction, limited servicing by the user is feasible provided skilled personnel and recommended equipment are available and the procedures outlined below are followed.

However, it should be pointed out that the described procedures are only simplified outlines of recommended service and calibration. Refined service and comprehensive calibration requires accurate and special equipment normally not available to the user. Therefore if trouble develops which cannot be corrected by the simplified methods outlined here or when accurate recalibration of the instrument is needed, it is recommended that the voltmeter be returned to Ballantine Laboratories for service and/or recalibration. If it should become necessary to return the instrument or any part thereof to Ballantine Laboratories, Inc. for examination or servicing, at least 4 inches of packing material should be placed around all sides of the instrument to prevent damage during shipment. Ship via Railway Express or motor truck. A letter describing the trouble or desired service will help our Service Department greatly and insure a fast return.

5.2 Necessary Equipment

For successful servicing and trouble shooting, the following equipment is needed.

5.2.1 A dc voltmeter, 1 V to 500 V full scale, 3% accuracy, 10 megohms input resistance.

5.2.2 A sensitive ac voltmeter, 10 cps to 100 kc, 1 mV to 100 V, 3% accuracy. Ballantine Model 300, 300D, 300H, 310A or 302C or equivalent.

5.2.3 Signal generator 50 cps to 50 kc, 0-1 V output.

5.2.4 0.05% or better accurate voltage calibrator, 0.1 to 100 V output, frequency range 50 cps to 20 kc. This may consist of a stable generator and an accurate voltage measuring device, such as NBS Transfer Standard voltmeter.

5.2.5 Ratio transformer, 0.005% or better accuracy, 10 steps from 1.0 to 0.1.

5.2.6 A general purpose, sensitive oscilloscope.

5.3 Simple Service Problems

5.3.1 The removal of the case is required for several of the tests. For the removal:

5.3.1.1 Place the instrument on a bench with front panel down.

5.3.1.2 Remove the power cord and unscrew, from the back, three #10 binder head screws.

5.3.1.3 Lift up the case.

To put the instrument back in the case proceed in reverse order.

WARNING . . . When instrument is operated without the case, the danger of electric shock exists. The highest voltage on one chassis is approximately 450 V dc. CARE SHOULD BE TAKEN NOT TO COME IN CONTACT WITH HIGH VOLTAGE POINTS.

5.3.2 Line voltage conversion from 115 V to 230 V can be done by connecting the transformer leads as follows:

For 115 V supply, connect black and black-green to terminal No. 1; Connect black-yellow and black-red to terminal No. 3. F 0.7A slow blowing.

For 230 V supply, connect black to terminal No. 1; black-yellow and black-green to terminal No. 2; black-red to terminal No. 3. F 0.375A slow blowing.

5.3.3 The tubes can be replaced with any tubes which meet the manufacturer's specifications. No selection of tubes is needed.

5.3.4 The replacement of the indicator (NIXIE) tubes is needed when the numbers are not completely lit. For replacement of the NIXIE tubes:

5.3.4.1 Take voltmeter out of the case.

5.3.4.2 Remove the polaroid screen by unscrewing the oxidized screws at the top of the screen. Remember which side of the screen was toward the tubes. The screen should be remounted with the same side against the tubes.

5.3.4.3 Take a long, thin screwdriver. Reach the NIXIE tube sockets from the top or from the side of the instrument. Rotate the cardboard shields until the slot in the shield is in the position which permits wedging the screwdriver under the tube. Support the tube with your fingers from the front and pry the tube out. Do not remove the cardboard shield.

Insert the new tube through the front panel.

The instrument is supplied with the regular Type 6844-A tubes. The long life Type B-5031 is direct replacement for these tubes.

5.3.4.4 If the voltmeter is used often to measure one particular voltage, it is possible that only one number in a NIXIE tube is burned out. In case this number is other than 1, the first tube in the display may be interchanged with this tube.

5.3.5 For fuse replacement, unscrew the fuseholder cap on the front panel and pull out the fuse. For replacement use

0.7A, slow blow, Type MDL for 115 V operation
0.375A, slow blow, Type MDL for 230 V operation

Before replacement the reason for fuse failure should be investigated and corrected.

5.3.6 Change of the decimal point light.

The burning out of a decimal point light should be very unlikely because the bulbs are working below the rated voltage. However, if the bulb needs replacement proceed as follows:

5.3.6.1 Remove the polaroid screen and two NIXIE tubes adjacent to the bulb to be changed. Remove the cardboard sleeves by pulling them out through the opening in the panel.

5.3.6.2 Reach the bulbs through the panel opening with your finger and remove the bulb from its bayonet socket and replace with GE 47 bulb or equivalent.

5.3.7 Cleaning or adjustment of the knob switch is needed if depressing the knobs B, C or D does not activate the relay K1 or does it intermittently. For the adjustment:

5.3.7.1 Remove the case and then remove the front frame by unscrewing the 6 binder head screws at the edge of the panel. The switch can now be seen between the panel and measuring attenuator chassis.

5.3.7.2 Observe the switch when operating knobs B, C and D. If the contacts do not make or break properly, bend the switch blades with a proper tool. If the contacts are making or breaking properly, clean the contacts with a relay cleaning tool or a very fine file.

5.3.8 Relay replacement or cleaning of the relay contacts may be needed when the voltmeter, either in accurate or approximate setting mode, exhibits erratic or intermittent operation.

For cleaning, remove the dust cover of the relay and clean the contacts with a relay cleaning tool or very fine file.

5.4 A DC Voltage Check should be undertaken when the voltmeter shows malfunctioning which cannot be corrected by replacing the burned or defective tubes.

5.4.1 For dc measurement, remove the case, short the input terminals, and

SET	TO
Range Selector	100-1000 V
Measuring Attenuator	100.0
Knobs B, C and D	Released

5.4.2 Measure tube pin voltages with 10 MΩ or higher input resistance voltmeter. Compare the results with the table below.

5.4.3 The voltages should be in ±25% of the stated values. If a voltage deviates more than ±25% of the tabulated value, check the associated tube, measure the components or inspect the connections until the reason for voltage deviation is found and corrected.

TUBE \ PIN	1	2	3	4	5	6	7	8
V1					2.2	40		80
V2		170	15		70	2.0		
V3			130					
V4			130					
V5			130					
V6			130					
V7			130					
V8					1.7	35		55
V9					2.5	100		145
V10	145	290	150	145	290	150		
V11	290	145	150			205		3.7
V12	140		1.5			145		1.5
V13	250				250		147	
V14	147				147			

5.5 Signal Tracing is recommended when the voltmeter malfunction cannot be found by the dc voltage measurments.

5.5.1 Signal tracing in amplifier and measuring attenuator circuit.

Apply 0.1 V, .4 to 2 kc signal to the input and

SET	TO
Range Selector	0.1-1 V
Measuring Attenuator	0.1000
Knobs B, C or D	Depressed

5.5.1.1 Measure the voltages at the amplifier points as indicated in the schematic. The values should be within ±10% of those shown on the circuit diagram.

5.5.1.2 Turn the knob A clockwise to the digit 0.2, 0.3, 0.4 etc. The voltage measured at the output amplifier should decrease by 1/2, 1/3, 1/4, etc.

5.5.2 For signal tracing in the null detector

SET	TO
Range Selector	0.1-1 V
Measuring Attenuator	0.1000
Knobs B, C or D	Depressed

5.5.2.1 Apply approximately 0.1 V, 0.4 to 2 kc, signal to the input. Vary the amplitude of the signal until 1 mV ±5% is measured at the pin 6 or 8 of AC Voltage Standard. Measure the voltage at pin 3 of tube V11. It should be 4 V min.

5.5.3 For signal tracing in the monitor voltmeter circuit

SET	TO
Range Selector	0.1-1 V
Measuring Attenuator	0.1000
Knobs B, C and D	Released

5.5.3.1 Apply 0.1 V ±1%, 0.4 to 2 kc, signal to the input. Measure voltage at pin 1 of tube V11. It should be within 5% of the value indicated on the circuit diagram.

5.5.3.2 At the same time measure the 60 cps signal at pin 4 of the AC Voltage Standard. It should be within 20% of the value indicated on the circuit diagram.

If any of the measured voltage values exceed the specified limits, stage by stage signal tracing should be used to locate the trouble.

5.6 Monitor Voltmeter Adjustment

When a signal is nulled accurately and the knobs B, C and D are released, the pointer of the indicator should indicate approximately 1/32 to 1/16" to the left of the center of the red triangle. If that is not the case adjust R84 as follows:

5.6.1 Remove the case. Apply any voltage, 0.4 kc to 2 kc. Measure the voltage by setting knobs A, B and D for minimum deflection.

5.6.2 Release all knobs and set R84 until the pointer indicates approximately 1/16" left of the red triangle. If the setting of the monitor sensitivity is correct, the monitor voltmeter indicates at the center of the red triangle when the knobs are set approximately 2% lower than the correct setting. Then when going from approximate setting to accurate setting, the knobs will always have to be turned clockwise. This simplifies the finding of the correct null.

5.7 R107 — Hum Balancing Adjustment needs readjustment if, when measuring signal of line frequency, the result changes when reversing the line plug of the voltmeter. This condition indicates excessive hum pickup in the input amplifier which can be corrected by readjusting R107.

For the adjustment of R107 remove the case. Short the input terminals and

SET	TO
Range Selector	1-10 V
Measuring Attenuator	1.000
Knobs B, C or D	Depressed

Connect a sensitive scope to the cathode of the output tube V10 (pin 3 or 6). Observe the noise waveform, and set R107 so that the 60 cps component in the noise has the minimum amplitude. This should be approximately equal to the amplitude of the random noise component.

5.8 Amplifier Sensitivity Adjustment is required when the voltmeter has an error of the same sign on all the ranges at midfrequency (0.4 kc-2 kc) measurements. The sensitivity can be adjusted by adjusting R13. This adjustment changes the sensitivity of all ranges and at all frequencies. To adjust R13 proceed as follows:

5.8.1 Measure the voltmeter error on all ranges. Connect a stable, 0.4 kc to 2 kc signal source, and an accurate (0.05% or better) voltage measuring device to the input of the voltmeter and

SET	TO
Range Selector	All Ranges
Measuring Attenuator	1000
Knobs B, C or D	Depressed

5.8.2 Adjust input to give null on the indicator. Measure the input voltage accurately. Compute the error (difference of indicated value from 1000) for every range. The error spread (maximum error less minimum error) should not exceed 0.15%.

5.8.3 Adjust R13 so that the magnitude of the greatest positive error equals the magnitude of the greatest negative error.

Example:

Range	Measured Error Before R13 Adjustment	Measured Error After R13 Adjustment
0.1-1V	+0.10%	−0.02%
1.0-10V	+0.20%	+0.08%
10.0-100V	+0.05%	−0.07%
100.0-1000V	+0.10%	−0.02%
spread	0.15%	

5.9 Amplifier Frequency Response Adjustment is needed when the instrument measured correctly midband frequencies (up to 2 kc) but exhibits error at higher frequencies on all voltage ranges. The amplifier response adjustment affects the response of all voltage ranges.

5.9.1 For amplifier frequency response adjustment, connect a stable, variable frequency generator and a 0.05% accurate voltmeter to the input of the Model 350. A calibrated source with a flat frequency response, such as the Ballantine Model 440 Micropotentiometer, may be used instead of a standard voltmeter in case the standard voltmeter range does not extend down to 0.1 V.

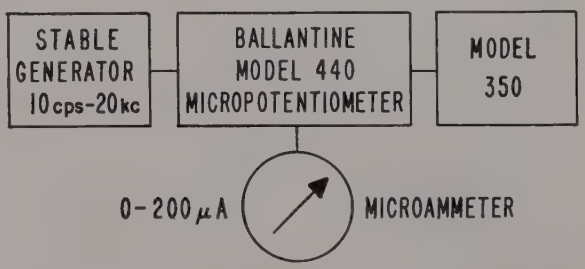


Figure 6 — Connection of Ballantine Model 440 Micropotentiometer for Amplifier Frequency Response Adjustment

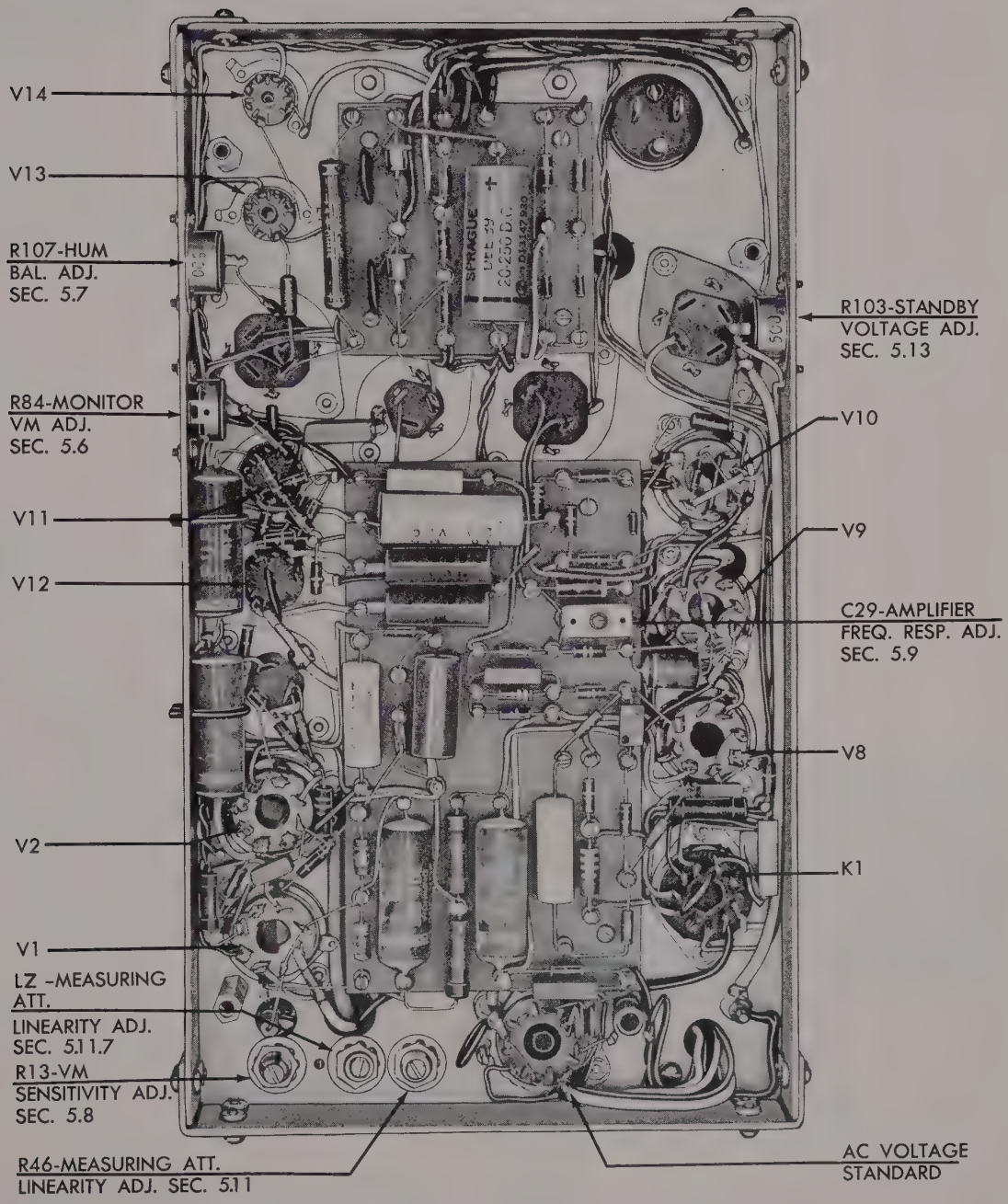


Figure 7 — Rear View of Model 350 Showing Adjustment and Tube Locations

5.9.2

SET	TO
Range Selector	0.1 V-1 V
Measuring Attenuator	0.1055
Knobs B, C or D	Depressed

Set voltage source to 1 kc.

Adjust the input level until the Model 350 indicator indicates minimum. Measure the input level with standard voltmeter or note the reading of the micropotentiometer.

5.9.3 Change the frequency to 10 kc. Adjust the input level to the same value (±0.02%) as for 1 kc. Measure the 10 kc voltage with Model 350. Calculate the deviation from 1 kc indication (0.1055). This should be 0.1% or less.

5.9.4 If the 10 kc indication differs by more than 0.1% from the 1 kc indication, set the Model 350 measuring attenuator to the same setting as for the 1 kc measurement, and adjust C29 **with insulated screwdriver** (upper plate of C29 carries B+ voltage) until null detector indicates minimum.

5.9.5 Check the error at 15 kc and 20 kc by measuring the same amplitude at 1 kc, 15 kc and 20 kc. The error should not exceed 0.3%.

5.10 Input Attenuator Frequency Response Adjustment is needed when excessive high frequency error is observed at one or several higher voltage ranges, but not on 0.1 V to 1 V range.

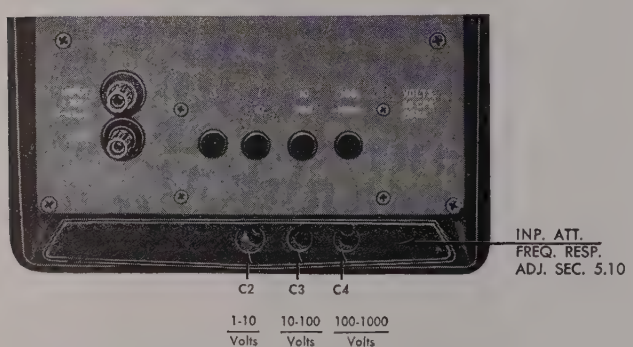


Figure 8 — Portion of Front View of Model 350 Showing Location of Input Attenuator Frequency Response Adjustments. Nameplate is removed for access.

If the high frequency measurement is in error at 0.1 V to 1 V range, the amplifier frequency response should be adjusted according to 5.9. This adjustment should be made prior to any adjustment of the attenuator response. The adjustment on every voltage range is independent.

5.10.1 Check the 0.1-1 V range error according to the 5.9.2 and 5.9.3. Note the error.

5.10.2 Connect proper voltage source, and standard voltmeter, to the input of the Model 350.

In place of standard voltmeter, Ballantine Model 393 HF Transfer Standard Voltmeter may be used.

SET	TO
Range Selector	The range checked
Measuring Attenuator	1055
Knobs B, C or D	Depressed

5.10.3 Feed a 1 kc signal to the Model 350 and adjust the level until null detector indicates minimum. Measure the level accurately. Note the result or setting of Model 393 Transfer Voltmeter.

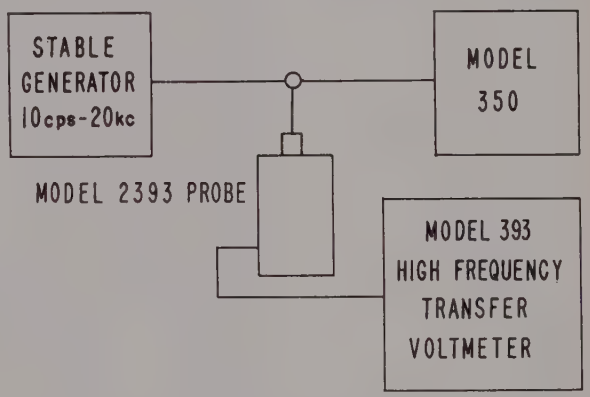


Figure 9 — Connection of Ballantine Model 393 Transfer Voltmeter for Attenuator Response Adjustment

5.10.4 Change the frequency to 10 kc; the level to the same value (0.02%) as for 1 kc. Set the measuring attenuator to have the same error as measured on 0.1 V -1 V range. Adjust the trimmer under the range button (left of the range button on rack mounted instruments) until null detector indicates a minimum.

5.10.5 The trimmer can be reached through the front panel, after removing the nameplate, by unscrewing two round head screws. A fine tip **insulated screwdriver** should be used for the adjustment.

5.10.6 Repeat steps 5.10.2 - 5.10.5 on other voltage ranges as required.

5.11 Linearity Adjustment of the Measuring Attenuator is needed when it exhibits no error at lower measuring attenuator settings (1000 to 3000) but excessive error at higher attenuator settings 10000 to 11000). For the adjustment:

5.11.1 Connect a stable, 0.4 kc to 1 kc, voltage source through an accurate (0.005% or better) ratio transformer to the input of the Model 350.

SET	TO
Ratio Transformer E_o/E_i	0.10000
Range Selector	0.1-1 V range
Measuring Attenuator	0.1000
Knobs B, C or D	Depressed

Adjust generator level until Model 350 null detector indicates minimum.

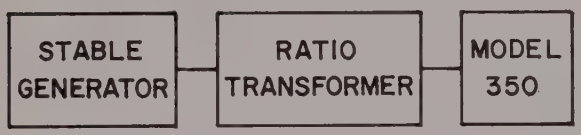


Figure 10 — Connection of Ratio Transformer for Measuring Attenuator Linearity Adjustment

5.11.2 Keep the generator output constant.

SET	TO
Ratio Transformer E_o/E_i	1.0000
Measuring Attenuator	1.000
Knobs B, C or D	Depressed

Adjust knobs C or D until null detector indicates minimum.

5.11.3 The error in the attenuator linearity is the deviation of the attenuator setting from the setting 1.0000. This error should not exceed 0.03%.
If the error exceeds 0.03% adjust R46 as follows:

5.11.4 Repeat the tests 5.11.1 and 5.11.2. On test 5.11.2 leave measuring attenuator setting to 1.0000, and adjust R46 until null indicator indicates minimum.

5.11.5 Test the linearity of the intermediate steps of the attenuator by stepping the measuring attenuator down in decade steps and correspondingly setting the ratio transformer to achieve minimum on null detector. The ratio transformer setting should agree with the Model 350 settings to 0.05%.

5.11.6 If the linearity error of the attenuator exceeds 0.05%, the resistors in the attenuator should be measured and corrected. The attenuator is a decade resistor box which is composed of resistors of values 1, 2, 2 and 5, which are connected in series in a manner to give all decade values. The resistors have ±1% nominal tolerance but they are matched to 0.05% in the two highest decades and less in the lower decades.

By measuring all the resistors in the decade, the matching of the set may be checked and the faulty resistor replaced.

5.11.7 The linearity of the measuring attenuator at higher frequency is adjusted by L2. For L2 adjustment connect a 20 kc 0.1 V stable source to the voltmeter.

SET	TO
Range Selector	0.1 — 1 V
Measuring Attenuator	0.1000
Knobs B, C, D	Depressed in normal measuring sequence

Adjust the source voltage until the Model 350 measures 0.1000 V.

Next, increase the source voltage exactly 10 times ±0.02%.

SET	TO
Range Selector	0.1 — 1 V
Measuring Attenuator	0.10000
Knobs B, C, D	Depressed in normal measuring sequence

Adjust L2 until the Model 350 measures 1.0000 V ±0.05%.

5.12 Change of the Thermostat in the AC Voltage Standard may be required after several thousand hours of operation when the thermostat contacts are worn. This will cause excessive temperature variation in the thermostat oven. The symptom of excessive temperature variation is slow change of voltmeter sensitivity in order of 0.1 — 0.2% over periods of a few minutes.

For the change of thermostat the Model 1350 AC Voltage Standard should be sent to Ballantine Laboratories, Inc., where the thermostat will be replaced. After receiving the AC Voltage Standard back, the sensitivity of the Model 350 should be checked according to 5.8 and readjusted if needed. The frequency response of the voltmeter does not need readjustment if only the thermostat is changed in the Model 1350 AC Voltage Standard.

5.13 R103 — Standby Voltage Adjustment is needed when the voltmeter exhibits small drift of approximately 0.1% during the few minutes period after being switched to the accurate measuring mode.

5.13.1 To adjust the standby voltage set the power line voltage to 115 V ±2%. Leave knobs released, connect an ac voltmeter to pin 3 of tube V11.

5.13.2 Adjust R103 until the ac voltmeter indicates 7 V or less. The indication will fluctuate when crystal oven is operating but the adjustment is sufficient when the highest voltage does not exceed 7 V.

5.14 Cleaning of Measuring Attenuator Switches is needed when the null indication exhibits small drifts when measuring attenuator knob is touched or turned slightly (without changing the digit). This effect may be caused by small deposits of insulating film, formed on the switch rotors and contacts, which may occur when voltmeter is operated in unfavorable environment. To eliminate the trouble the cover of the switch causing the drift should be removed, and the switch rotor and contacts cleaned, using carbon tetrachloride. This operation will not require the recalibration of the voltmeter.

5.15 Trouble Shooting Chart

In the following chart the effects of possible malfunction of an assembly or component are described.

Symptoms	Possible Cause	Pertinent Section
Instrument inoperative; NIXIE display does not light up	No power; blown fuse; Defect in power supply	5.3.5
Instrument operative; one or more digits on the display do not light up	Defective display tube; Defective switch or wiring on measuring attenuator chassis	5.3.4
Operation normal in approximate measuring mode; inoperative in accurate mode	Defect in output amplifier, AC Voltage Standard, null detector or knob switch	5.5.1; 5.5.2 5.3.7.; 5.4;
Operation normal in accurate mode; inoperative in approximate mode	Defect in monitor voltmeter or relay	5.3.7; 5.3.8; 5.5.3
Insufficient null detection sensitivity	Weak tube or defect in null detector circuit	4.6.3; 5.4; 5.5.2
Incorrect indication in approximate setting position	R84 misadjusted; weak tube, or defect in monitor voltmeter circuit	4.6.4; 5.6; 5.4; 5.5.3
Errors with high setting of measuring attenuator	Incorrect setting of R46; Excessive noise or hum in amplifiers	5.11; 5.7
Error of all ranges when measuring high frequencies	Incorrect setting of amplifier frequency response	5.9
Error when measuring high frequencies on 1-1000 V ranges only	Incorrect setting of attenuator frequency response (C2, C3 or C4)	5.10
Error when measuring 60 cps	Excessive hum, incorrect setting of R107, bad tube in input amplifier	5.7
Small drifts during the first minute of accurate mode	Incorrect setting of standby voltage to AC Voltage Standard (R103)	5.13
Small slow drift of 1-5 minute duration	Defective thermostat	5.12
Excessive effect of line voltage change	Weak tube in amplifier circuits or defect in power supply	4.6.2; 5.4; 5.5.1
Intermittent drift when measuring attenuator knob is touched	Insulating deposit may be formed on attenuator switches	5.14

REPLACEMENT PARTS LIST

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B. L. Part No.	*Circuit Symbol*	*Capacitors*	*Manufacturer*
2135	C1	.033 μF, 20%, Type 621S, 600 V	Goodall
2437	C2	0.5-8 pF, Type VC1G, 1000 V	JFD
2437	C3	0.5-8 pF, Type VC1G, 1000 V	JFD
2437	C4	0.5-8 pF, Type VC1G, 1000 V	JFD
2235	C5	33 pF, Type CM15E330J, 500 V	Arco
2254	C6	330 pF, Type CM15E331J, 500 V	Arco
2253	C7	3300 pF, Type CM-30-E-332J, 500 V	Arco
2319	C8	2 μF, 5%, Type PUP, 200 V	Cornell-Dubilier
2254	C9	330 pF, Type CM15E331J, 500 V	Arco
2006	C10A	20 μF, Type DFP, 300 V	Sprague
	C10B	20 μF, Type DFP, 300 V	Sprague
	C10C	20 μF, Type DFP, 25 V	Sprague
2362	C11	.22 μF, 5%, Type 355C224J, 200 V	Gudeman
2319	C12	2 μF, 5%, Type PUP, 200 V	Cornell-Dubilier
2081	C13	50 μF, Type BB12, 25 V	Cornell-Dubilier
2225	C16	8 pF, Type CM15C-080J, 500 V (C16 used only in Ser. #3, 4, 5, 6, 8, 9, 11, 12, 15, 16, 18, 19, 21, 22, 23, 24, 25, 26, 29, 30, 31, 32, 33, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 50, 91, 93, 94, 95, 96, 97, 100)	Arco
2225	C17	8 pF, Type CM15C-080J, 500 V (C17 used only in Ser. #3, 4, 5, 6, 8, 9, 11, 12, 15, 16, 18, 19, 21, 22, 23, 24, 25, 26, 29, 30, 31, 32, 33, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 50, 91, 93, 94, 95, 96, 97, 100)	Arco
2373	C20	.047 μF, 5%, Type 355C473M, 200 V (Ser. #1 thru 100, C20 was Part #2364, .033 μF, 5%, Type 355C333J, 200 V)	Gudeman
2759	C21A	30 μF, Type FP, 350 V	Sprague
	C21B	50 μF, Type FP, 350 V	Sprague
2226	C22	3 pF, Type CM-030M, 500 V	Arco
2215	C23	250 pF, 10%, Type CM-20-251	Arco
2319	C24	2 μF, 5%, Type PUP, 200 V	Cornell-Dubilier
2205	C25	500 pF, 20%, Type 5W	Cornell-Dubilier
2362	C26	.22 μF, 5%, Type 355C224J, 200 V	Gudeman
2258	C27	390 pF, Type CM15E-391J, 500 V	Arco
2302	C28	.25 μF, 5%, Type PUP, 200 V	Cornell-Dubilier
2409	C29	400 pF, Type 42-429	Arco
2758	C30	320 μF, Type DFP, 300 V	Sprague
2542	C31	1.0 μF, Type HCC3105P	Cornell-Dubilier
2284	C32	100 pF, 5%, Type CM15E-101-J, 500 V	Arco
2306	C36	0.5 μF, Type PUP, 400 V	Cornell-Dubilier
2205	C37	500 pF, 20%, Type 5W, 500 V (Ser. #1 thru 200, C37 was Part #2210, 1,000 pF, 5%, Type 1W, 500 V)	Cornell-Dubilier

REPLACEMENT PARTS LIST *Continued*

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B. L. Part No.	*Circuit Symbol*	*Capacitors*	*Manufacturer*
2351	C38	1 μF, 10%, Type 621M, 200 V	Goodall
2779	C39A	40 μF, Type DFP, 250 V (Ser. #1 thru 300, was Part #2030, 10 μF, Type FP, 450 V)	Sprague
	C39B	25 μF, Type DFP, 150 V (Ser. #1 thru 300, was Part #2030, 30 μF, Type FP, 450 V)	Sprague
2064	C40	25 μF, Type BBR, 6 V	Cornell-Dubilier
2538	C41	.01 μF, Type BYA-10S1	Erie
2064	C42	25 μF, Type BBR, 6 V	Cornell-Dubilier
2540	C45	.005 μF, Type EGP25U851	Erie
2373	C46	.047 μF, 20%, Type 355C473M, 200 V	Gudeman
2540	C48	.005 μF, Type EGP25U851	Erie
2540	C49	.005 μF, Type EGP25U851	Erie
2540	C50	.005 μF, Type EGP25U851	Erie
2053	C51	20 μF, Type DEE, 250 V	Sprague
2007	C52A	20 μF, Type DFP, 450 V	Sprague
	C52B	80 μF, Type DFP, 350 V	Sprague
		Resistors	
1076	R1	22 ohms, 5%, Type EB	Allen-Bradley
1476	R2(1)	1,800,000 ohms, 1%, Type PT-1000	Pyrofilm
1477	R3(2)	2,000,000 ohms, 1%, Type PT-1000	Pyrofilm
1477	R4(3)	2,000,000 ohms, 1%, Type PT-1000	Pyrofilm
1026	*R5	100,000 ohms, 5%, Type EB (Ser. #1 thru 300, R5 was Part #1042, 15,000 ohms, 5%, Type EB)	Allen-Bradley
1028	*R6	68,000 ohms, 5%, Type EB	Allen-Bradley
1085	*R7	120,000 ohms, 5%, Type EB	Allen-Bradley
1007	R8	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1441	R9(1)	200,000 ohms, 1%, Type PT-500	Pyrofilm
1442	R10(2)	20,200 ohms, 1%, Type PT-500	Pyrofilm
2693	R11(3)	2,002 ohms, 1%, Type PT-500	Pyrofilm
1317	R12	34,000 ohms, 1%, Type CP-½	Hi-Q Aerovox
1929	R13	50,000 ohms, Type CLU, 10%	Allen-Bradley
1392	R14	900,000 ohms, 1%, Type CP-½	Hi-Q Aerovox
2687	R15	600 ohms, 1%, Type PT-500 (Ser. #1 thru 100, R15 was Part #2682, 615 ohms, Type PT-500)	Pyrofilm

Note: Matched-set resistors MUST be replaced as a complete set in order to provide the specification accuracy.

(1) Resistors R2 and R9 are a matched set and should be ordered as Resistor Set No. 1564.

(2) Resistors R3 and R10 are a matched set and should be ordered as Resistor Set No. 1563.

(3) Resistors R4 and R11 are a matched set and should be ordered as Resistor Set No. 1595.

* The value of this item is determined during the calibration of the instrument and may differ from the value listed.

REPLACEMENT PARTS LIST *Continued*

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
——	*R16	Varies from 6 to 25 ohms, 10%, Special	Ballantine
1460	R17	2,000,000 ohms, 1%, Type CP-1	Hi-Q Aerovox
1043	R18	12,000 ohms, 5%, Type EB	Allen-Bradley
1007	R19	2,000,000 ohms, 5%, Type EB	Allen-Bradley
2686	R20	2,400 ohms, 1%, Type PT-500 (Ser. #1 thru 100, R20 was Part #2693, 2,002 ohms, 1%, Type PT-500)	Pyrofilm
1057	R21	1,000 ohms, 5%, Type EB	Allen-Bradley
1274	R22	51,000 ohms, 5%, Type GB	Allen-Bradley
1043	R23	12,000 ohms, 5%, Type EB	Allen-Bradley
1010	R24	1,000,000 ohms, 5%, Type EB	Allen-Bradley
1057	R25	1,000 ohms, 5%, Type EB	Allen-Bradley
1044	R26	10,000 ohms, 5%, Type EB	Allen-Bradley
1369	R30	20 ohms, 1%, CP-½	Hi-Q Aerovox
1369	R31	20 ohms, 1%, Type CP-½	Hi-Q Aerovox
2685	R32	10 ohms, 1%, Type CP-½	Hi-Q Aerovox
2684	R33	50 ohms, 1%, Type CP-½	Hi-Q Aerovox
1351	R34	200 ohms, 1%, Type CP-½	Hi-Q Aerovox
1351	R35	200 ohms, 1%, Type CP-½	Hi-Q Aerovox
1355	R36	100 ohms, 1%, Type CP-½	Hi-Q Aerovox
2676	R37	500 ohms, 1%, Type CP-½	Hi-Q Aerovox
2681	R38(4)	2,000 ohms, 1%, Type PT-500	Pyrofilm
2681	R39(4)	2,000 ohms, 1%, Type PT-500	Pyrofilm
2697	R40(4)	1,000 ohms, 1%, Type PT-500	Pyrofilm
2696	R41(4)	5,000 ohms, 1%, Type PT-500	Pyrofilm
2695	R42(4)	20,000 ohms, 1%, Type PT-500	Pyrofilm
2695	R43(4)	20,000 ohms, 1%, Type PT-500	Pyrofilm
2683	R44(4)	10,000 ohms, 1%, Type PT-500	Pyrofilm
2683	R45	10,000 ohms, 1%, Type PT-500	Pyrofilm
1837	R46	200 ohms, 10%, Type 43-200	Clarostat
2694	R47(4)	50,000 ohms, 1%, Type PT-500	Pyrofilm
1114	R48	82,000 ohms, 5%, Type EB (Ser. #1 thru 300, R48 was Part #1029, 56,000 ohms, 5%, Type EB)	Allen-Bradley
1114	R49	82,000 ohms, 5%, Type EB (Ser. #1 thru 300, R49 was Part #1029, 56,000 ohms, 5%, Type EB)	Allen-Bradley
1114	R50	82,000 ohms, 5%, Type EB (Ser. #1 thru 300, R50 was Part #1029, 56,000 ohms, 5%, Type EB)	Allen-Bradley
1114	R51	82,000 ohms, 5%, Type EB (Ser. #1 thru 300, R51 was Part #1029, 56,000 ohms, 5%, Type EB)	Allen-Bradley

* The value of this item is determined during the calibration of the instrument and may differ from the value listed.

(4) Resistors R38, R39, R40, R41, R42, R43, R44 and R47 are a matched set and should be ordered as Resistor Set No. 1592.

REPLACEMENT PARTS LIST *Continued*

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1114	R52	82,000 ohms, 5%, Type EB (Ser. #1 thru 300, R52 was Part #1029, 56,000 ohms, 5%, Type EB)	Allen-Bradley
1461	R55	1,000,000 ohms, 1%, Type CP-1	Hi-Q Aerovox
1023	R56	200,000 ohms, 5%, Type EB (Ser. #1 thru 100, R56 was Part #1022, 220,000 ohms, 10%, Type EB)	Allen-Bradley
1023	R57	200,000 ohms, 5%, Type EB (Ser. #1 thru 100, R57 was Part #1022, 220,000 ohms, 10%, Type EB)	Allen-Bradley
1017	R58	390,000 ohms, 5%, Type EB	Allen-Bradley
1081	R59	27,000 ohms, 5%, Type EB	Allen-Bradley
1057	R60	1,000 ohms, 5%, Type EB	Allen-Bradley
1461	R61	1,000,000 ohms, 1%, Type CP-1	Hi-Q Aerovox
1048	R62	4,700 ohms, 5%, Type EB	Allen-Bradley
1087	R63	22,000,000 ohms, 5%, Type EB	Allen-Bradley
1067	R64	22,000,000 ohms, 5%, Type EB (Used only in Ser. #1 thru 200)	Allen-Bradley
1102	R65	1,800,000 ohms, 5%, Type EB	Allen-Bradley
1016	R66	470,000 ohms, 5%, Type EB (Ser. #1 thru 100, R66 was Part #1024, 150,000 ohms, 5%, Type EB)	Allen-Bradley
1068	R67	100 ohms, 5%, Type EB	Allen-Bradley
1085	R68	120,000 ohms, 5%, Type EB	Allen-Bradley
1040	R69	20,000 ohms, 5%, Type EB	Allen-Bradley
1054	R70	2,000 ohms, 5%, Type EB	Allen-Bradley
1061	R71	510 ohms, 5%, Type EB	Allen-Bradley
1745	R72	12,000 ohms, Type 151E	Sprague
1273	R73	9,100 ohms, 5%, Type GB	Allen-Bradley
1770	R74	13.35 ohms, Special	Ballantine
1771	R76	2.40 ohms, Special	Ballantine
1057	R80	1,000 ohms, 5%, Type EB	Allen-Bradley
1043	R81	12,000 ohms, 5%, Type EB	Allen-Bradley
1030	R82	51,000 ohms, 5%, Type EB	Allen-Bradley
1052	*R83	2,700 ohms, 5%, Type EB	Allen-Bradley
1838	R84	500 ohms, 20%, Type WC818	Wirt
1010	R85	1,000,000 ohms, 5%, Type EB	Allen-Bradley
1044	R86	10,000 ohms, 5%, Type EB	Allen-Bradley
1042	R87	15,000 ohms, 5%, Type EB	Allen-Bradley
1057	R88	1,000 ohms, 5%, Type EB	Allen-Bradley
1036	R89	33,000 ohms, 5%, Type EB	Allen-Bradley
1028	R90	68,000 ohms, 5%, Type EB	Allen-Bradley
1085	R91	120,000 ohms, 5%, Type EB	Allen-Bradley
1026	R92	100,000 ohms, 5%, Type EB	Allen-Bradley

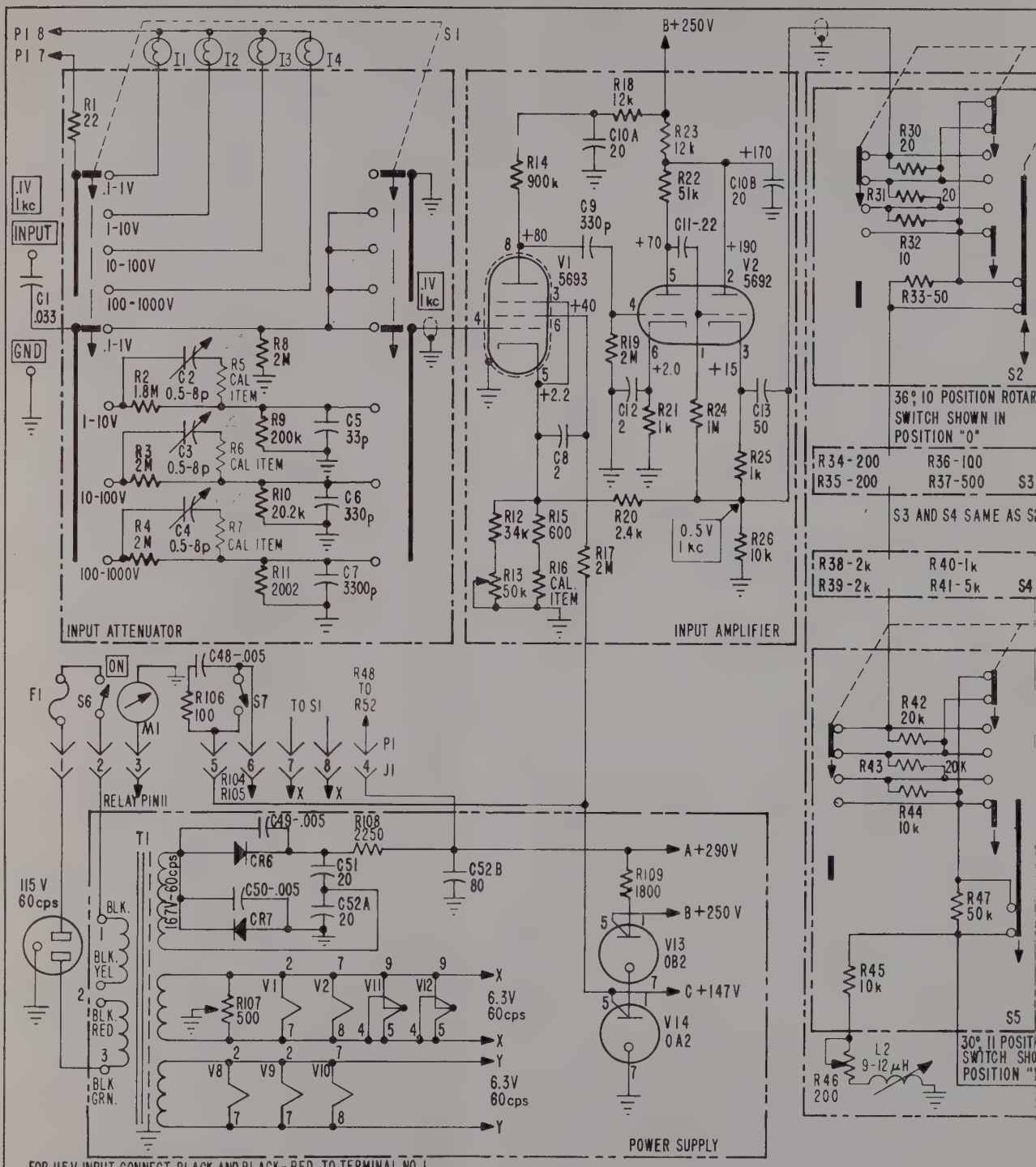
* The value of this item is determined during the calibration of the instrument and may differ from the value listed.

REPLACEMENT PARTS LIST *Continued*

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1048	R93	4,700 ohms, 5%, Type EB	Allen-Bradley
1022	R94	220,000 ohms, 5%, Type EB	Allen-Bradley
1007	R95	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1022	R96	220,000 ohms, 5%, Type EB	Allen-Bradley
1048	R97	4,700 ohms, 5%, Type EB	Allen-Bradley
1067	R100	150 ohms, 5%, Type EB	Allen-Bradley
1065	R101	200 ohms, 5%, Type EB	Allen-Bradley
1069	R102	56 ohms, 5%, Type EB	Allen-Bradley
1838	R103	500 ohms, 20%, Type WC818	Wirt
1201	R104	20,000 ohms, 5%, Type HB (Ser. #1 thru 300, R104 was Part #1270, 33,000 ohms, 5%, Type GB)	Allen-Bradley
1043	R105	12,000 ohms, 5%, Type EB	Allen-Bradley
1068	R106	100 ohms, 5%, Type EB	Allen-Bradley
1838	R107	500 ohms, 20%, Type WC818	Wirt
1747	R108	2,250 ohms, Type 28E (Ser. #1 thru 125, R108 was Part #1627, 1,500 ohms, Type 28E. If replacement is required use Part #1747, 2,250 ohms)	Sprague
1707	R109	1,800 ohms, 5%, Type 452E (Ser. #201 thru 300, R109 was Part #1738, 1,250 ohms, 5%, Type 151E; ser. #1 thru 200, R109 was Part #1744, 700 ohms, 5%, Type 151E)	Sprague
1019	*R110	330,000 ohms, 5%, Type EB (Ser. #1 thru 200, R110 was Part #1024, 150,000 ohms, 5%, Type EB)	Allen-Bradley
		Other Components	
3016	L1	2-5 mH Coil 4-426	Delta
3021	L2	Inductor, Variable 9-12.5 mH	Ballantine
3057	T1	Power Transformer	Ballantine
3058	T2	Output Transformer	Ballantine
3418	F1	0.7 amp Fuse, Type 3AG, Slo Blo	Littelfuse
3451	I1, 2, 3, 4	Pilot Light, Type 47	General Electric
3198	M1	Indicating Meter	Ballantine
3275	S1	Switch, Push Button, Special	Ballantine
3277	S2, 3, 4	Switch, Rotary, Special	Ballantine
3276	S5	Switch, Rotary, Special	Ballantine
3268	S6	Switch, Toggle, ON-OFF	Ballantine
3274	S7	Switch, Stack, Special	Ballantine
3125	V1	Tube, Type 5693	RCA

* The value of this item is determined during the calibration of the instrument and may differ from the value listed.



FOR 115V INPUT, CONNECT BLACK AND BLACK-RED TO TERMINAL NO.1, CONNECT BLACK-YELLOW AND BLACK-GREEN TO TERMINAL NO.3, F1-0.7 AMP. SLOW BLOWING.
FOR 230V INPUT, CONNECT BLACK TO TERMINAL NO.1; BLACK-YELLOW AND BLACK-RED TO TERMINAL NO.2, BLACK-GREEN TO TERMINAL NO.3 F1-3/8 AMP. SLOW BLOWING.

CAPACITORS: NOT MARKED - MICROFARADS (10^{-6} F)
P ——— PICOFARADS (10^{-12} F)
RESISTORS: NOT MARKED - OHMS (Ω)
K ——— KILOHMS (10^{3} Ω)
M ——— MEGOHMS (10^{6} Ω)
VOLTAGES: NOT MARKED - VOLTS (V)
mV ——— MILLIVOLTS (10^{-3} V)

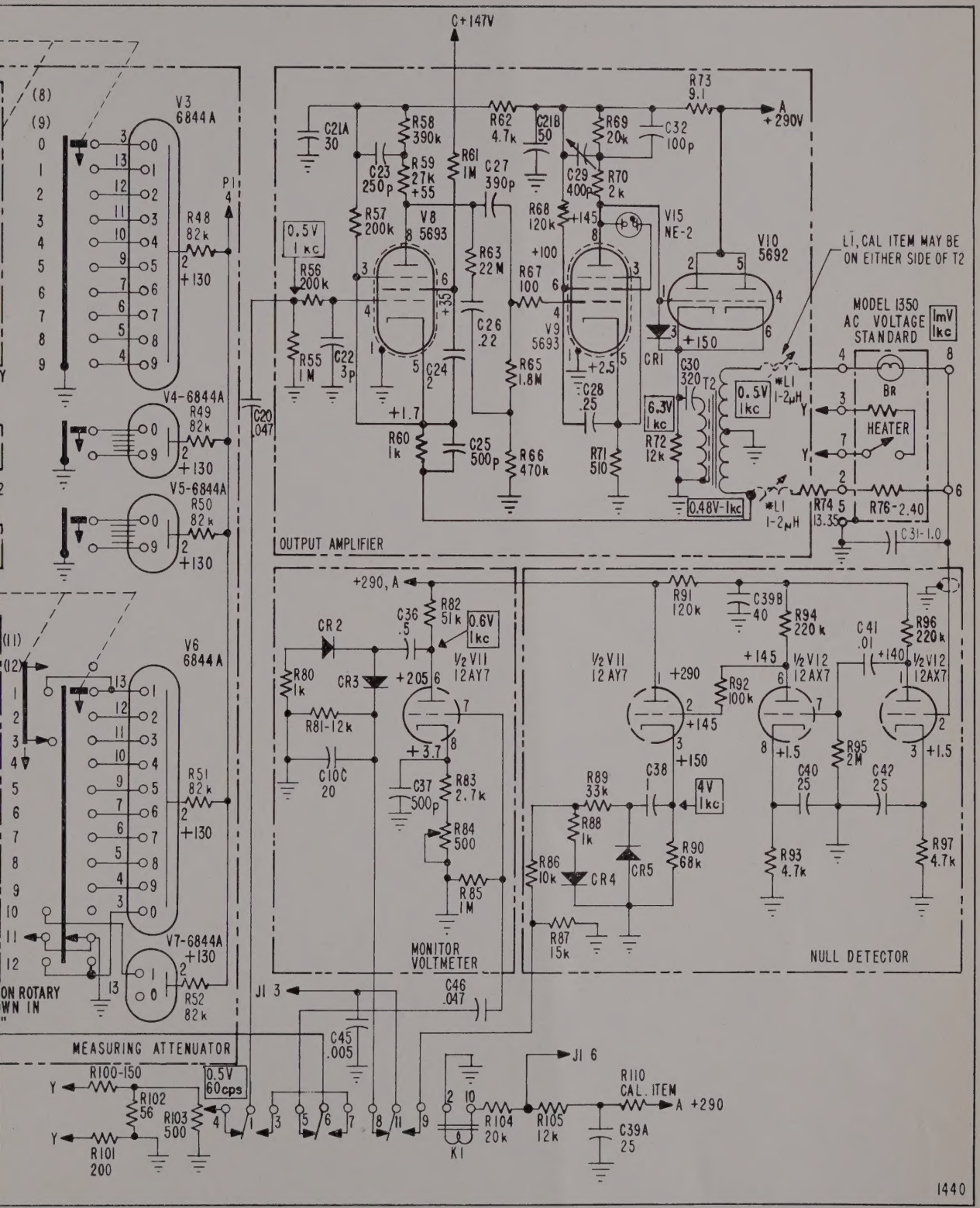


Figure 11 — Circuit Diagram, Model 350 Precision RMS Voltmeter. Ballantine Drawing MC-1440N.

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

REPLACEMENT PARTS LIST *Continued*

REFER TO MODEL 350 CIRCUIT DIAGRAM, DWG. MC-1440N

B.L. Part No.	*Circuit Symbol*	*Other Components*	*Manufacturer*
5583	V2	Tube, Type 5692	RCA
5581	V3, 4, 5, 6, 7	Tube, Type 6844-A	Burroughs
3125	V8, 9	Tube, Type 5693	RCA
5583	V10	Tube, Type 5692	RCA
3115	V11	Tube, Type 12AY7	RCA
3140	V12	Tube, Type 12AX7	RCA or GE
3128	V13	Tube, Type OB2	RCA or GE
3106	V14	Tube, Type OA2	RCA or GE
3138	V15	Lamp, Type NE-2 (V15 was used only in Ser. #1, 2, 7, 10, 13, 14, 17, 20, 27, 28, 34, 39, 48, 49, 51 and thereafter)	General Electric
5562	CR1, 4, 5	Diode, Type SG22	Transitron
5591	CR2, 3	Diode, Type IN625 (Ser. #1 thru 200, CR2, 3 were Part #5562, Diode, Type SG22)	Sperry
5574	CR6, 7	Rectifier, Type 1N1763	RCA
5562	CR8	Diode, Type SG22 (CR8 was used only in Ser. #38, 41, 43, 44, 46, 47, 50, 96 and 97. If replacement is required use Lamp V15)	
5556	RT101	Resistor Lamp	Ballantine
4491	——	AC Voltage Standard, complete	Ballantine

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